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The Spatial Dimension of Technology Policy: A framework for evaluating the systemic effects of technological innovation

Paper

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Abstract

Since the decline of aggregate economic growth rates in the 1970's and the ensueing changes in the international division of labour, innovation is increasingly being considered the key factor in national as well as regional and local development. Innovation requires a "scientific infrastructure" and close (synegetic) interaction of potentially innovative actors, particularly research and training, government, services, and production units. This applies to all the spatial levels mentioned.
Some countries have applied technology policy in a general aspatial form, others in spatially concentrated (national science city type) or spatially decentralized form (e.g. the Japanese Technopolis policy). In view of the systemic character of new technologies, important criteria for their success are their permeating effects primarily in three dimensions: horizontally from high-tech to traditional sectors, vertically between firms of different size, and spatially between different locations and regions.

Examples of different types of regional innovation strategies are given such as centrally (Central Government/large firm) externally implanted innovation, regionally (Local Government - local university, local enterprise/community) initiated innovation. Finally a framework for the analysis of their permeating effects is offered.

1. The changing role of technology policy for regional development

Whereas during the reconstruction and growth period of the three decades following World War II, **capital** was widely considered the scarcest factor and therefore the key to economic development, during the past decade this role is increasingly being attributed to **technology.** Some of the capital-intensive sectors which served as motors in industrialized countries during the first mentioned phase (such as heavy industry, mining and certain consumer goods sectors) are regionally concentrated and have ceased to expand. They are receiving increasing competition from newly industrializing countries and from technology-intensive sectors which are concentrating in different locations. This brings about drastic changes in the spatial structure of development.

The role of technology for development is receiving particular emphasis since the 1970,s on account of the hypothesis of an immanent down-swing in a Kondratieff-type wave in which radical
technological innovation is considered the key determinant for a new up-swing (Freeman 1984). As a consequence many countries, since the 1970ies, have focussed their previous general **research promotion policies** in much more concrete terms towards industrial technological innovation and have geared their **economic policy instruments** increasingly towards industrial research and development. During the 1980-ies, finally, explicit attention has been given by an increasing number of national, regional, and local governments also to the spatial dimension of the technology policy by the promotion of concentrations of high-tech activities in research and science parks.

Technological innovation can emerge

- **spontaneously** or be
- **induced.**

In many areas technological innovation has in the past taken place **spontaneously** and we shall call these (spontaneous) **technology or innovation complexes** (see also Stöhr 1986/a). Like Perroux's (1955) spontaneous" growth poles" they of course also have not happened automatically (in a God-given fashion) but by decentralized initiative of economic decision-makers. From this were successively derived the policy versions of **induced** growth centers, which in technology oriented policy correspond to **Research/Science Parks** usually induced by governmental or other institutions at different levels.

To induce technological development, technology policy has been applied

- in **general (aspatial) terms,**
- in **spatially concentrated** and
- in **decentralized** form.

Technology policy has been practiced since WW II **in general terms** by most countries at the national level via public research institutes, research funds, and more recently by incentives, subsidies or loan garanties to R & D, prototype development, etc.. Some countries have later on undertaken **spatially concentrated** innovation policies by the establishment of new science cities, the more outstanding and earlier examples of which are Tsukuba outside of Tokyo in Japan (founded 1970) and Sophia Antipolis in the South of France (founded 1974). Japan furthermore is the country which, beyond this, has recently undertaken a systematic **decentralised polycentric** technological innovation policy "Technopolis" which has been described by this author elsewhere (Stöhr 1986/b), building on related local initiatives particularly on the Southern Japanese island of Kyushu.

In the U.S. there exist a great number of predominantly **"spontaneous"** local high-technology development programs initiated by universities and the private sector (OTA 1984, Levitt 1985). Furthermore there are **mixes between "spontaneous"** local technology projects **and local or State government "induced"** ones in at least 22 States of the U.S. (OTA 1984). - Following these examples similar efforts have been undertaken also in Great Britain (Hall 1985), the Federal Republic of Germany (Krist 1984) and since then in many other countries.

2. The institutional setting of technological innovation in development

The institutional setting of technological innovation has changed considerably over time. Technological innovation was in fact practised ever since man in prehistoric times experimented with fire, tools and other implements in order to extend the abilities of his body. **Until the industrial revolution** technological development took place **in direct relation with production,** at first integrated in households and later on in increasingly specialised professional activities, workshops, and firms.

When **science emerged** it was predominantly speculative and remained for a long time **separated** from technological innovation - as e.g. in the early Greek period (Aristotle and Ptolemy) and in the Middle Ages - and reserved to a narrow class of persons where "science -.... belonged to the aristocratic philosophers -.. while technology was the position of the working crafts men" (Buchanan 1978).

Even with the advent of what is today called the **"first" industrial revolution, technological innovations** mainly took place **separated from science** and frequently even before systematic scientific research matured. Colombo and Lanzavecchia (1985) point out that for instance the steam engine was in practical use in mines and the textile industry considerable time before thermo-dynamic theory was formulated, and the steam locomotive was already on rails when Carnot wrote his "Reflexions sur la Puissance de Motrice a Feu". In fact during the major part of the first industrialisation period industrial technological innovation took place "essentially autonomous from centers of power and traditional knowledge" (p.12), i.e. from governmental and scientific institutions.

A **close relationship** between science and technological innovation took place only as late as the **end of the 19th century** with the break-throughs and direct application of electrical and electro-magnetic knowledge. Some authors date the first modern industrial technological research laboratory to 1879 when Edison developed the carbon filament for his electric light bulb at Menlo Park, New Jersey (Buchanan 1985). The following decades were **dominated by in-company R & D** particularly in the electrical, chemical, later also in the machine, metallurgical, optical, automobile and aviation industries in countries such as Germany and the U.S.. This dominance of in-company research led to an increasing **concentration of R & D in a few large firms** in each sector.

Parallel to this, **in the course of the 19th century** in Germany and other industrialised countries **politechnical schools** were established for the training of technicians. By the end of the century many of these schools were elevated to university level. Both these types of schools led to a considerable **broadening of technical knowledge,** although initially they were little oriented towards applied research. This changed first in the U.S. when some of the richest private companies created **foundations** (Rockefeller, Carnegie, Ford) which founded powerful research centers at universities. This led, particularly in the U.S., to a **tight bond** not only **between science and industry,** but also **between basic and applied research** (Colombo and Lanzavecchia 1985, p.7).

Research and innovation policy was put **on a broader basis** in most countries only during and after World War II, e.g. in France with the creation of the Centre National des Recherches Scientifiques in 1939, in the United States with the creation of the National Science Foundation in 1950, in the U.K. especially with the creation of the Ministry of Technology in 1964 to allocate funds to private industry for research projects. It was particularly the later evolving space programs however "which, due to their complex requirements, brought government, industry, and universities together in a single effort" (Colombo and

Lanzavecchia 1985, p.15). But new technologies are moving from specific to systemic aspects also in terrestral sectors: "The role of systemists in machine tool use and in factory automation; the penetration of informatics into the economy with the transformation of sectors, firms and activities at the systems organisation level; the development of bio- technologies destined, like informatics, to penetrate all economic activities, where they must necessarily interact systemically with the complex of other technologies". (p.36).

Colombo and Lanzavecchia show that recently "the center of gravity of technology is moving from specific to systemic aspects" (p.36) and that the criterion for technological competitiveness is a society's ability to operate "integrated systems management of technologies, which is both a generator of results and itself a source of overall flexibility and reliability" (p.37). SDI and, to a lesser extent, EUREKA are efforts towards integrated systems management of technologies.

The above survey shows that research and development oriented functions have been reorganised frequently in the course of time particularly in its relationship to production and consumption, to companies and their related foundations, to training institutions, local, regional, and national government etc.. Different types of technology require different organisational forms of research and development and specific relations to the other functions mentioned. Colombo and Lanzavecchia (1985) e.g. maintain that the rapid technological advances of German industry around the turn of the century and the parallel loss of momentum in Great Britain was due to the increasing role of the State in technical development in Germany, while in Britain the State was concentrating attention on the up-keep of Empire in administrative, financial and bureaucratic terms rather than on scientific progress (p.4).

3. The case for local/regional technology policy

Central government directly sponsored R + D (frequently concentrated in defense areas) often has little positive effect on productivity (Wiewel et al. 1984, p. 294). Equally, economy-wide aspatial technology policy has little positive effects as "no universal policy covering firms in different markets and technological environments is likely to lead to an efficient rate and direction of technological innovation" (Noll 1974, p.28) because of "different competetive pressure and market opportunities, different technological opportunities, and different availability of university-sponsored basic & applied research" (Wiewel et al. 1984, p.294).

On the other hand, the development path of local economies is considerably determined by their capacity for sustained innovation and self-renewal (Shapero 1981). Nelson and Winter (1977, p.40) argue that it is more important to build institutions that can "allocate resources appropriately over a wide range of circumstances and time "than it is to achieve particular allocations at any one time. Such local institutions will also be able to "specifically support what is possible and available locally, rather than in attempts to create glamorous microelectronics and gene-splicing research centers in every town" (Wiewel 1984, p.294).

4. The pervasive character of the "new" technologies

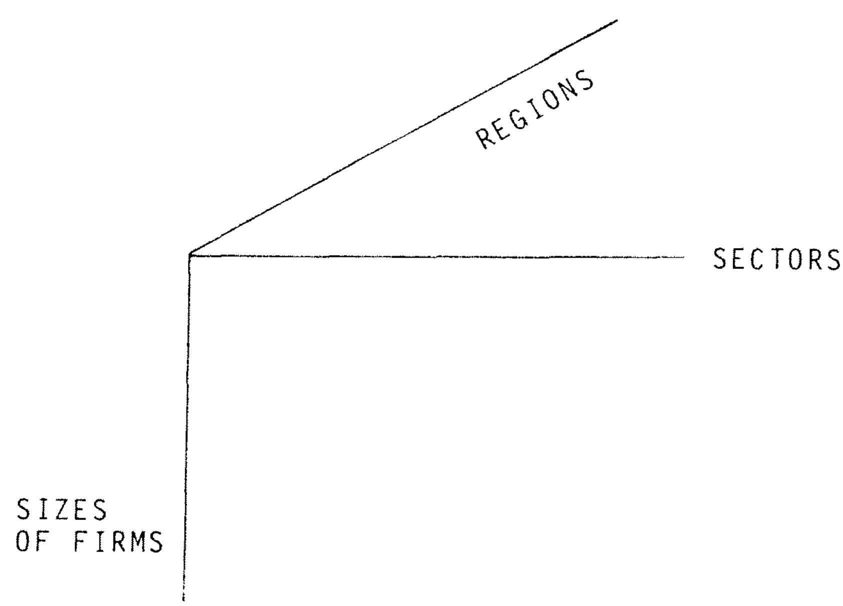
The "new" technologies based on microelectronics are considered a radical innovation in the sense that they potentially can permeate all economic sectors and human activities, just as the steam engine during the first industrial revolution. We shall call this the potentially pervasive character of the "new" technologies.

In view of the systemic character of these innovations described above, the success of technological innovation based on micro-electronics, depends to a great extent on whether the required technological, organizational and social transformations can actually take place in the

entire system of economic and human activities. If only a small number of "high-technology" sectors are created in enclave-like form whereas "traditional" sectors remain widely untouched by it, technological disparities will increase rather than decline; the same would be the case if only a few large enterprises in specific sectors would take advantage of (or monopolise) technological innovation whereas the medium and small enterprises would hardly be affected by it; similar inadequacies would emerge if only the highly developed core regions of individual countries would be able to take advantage of these innovations whereas the remaining areas would hardly be touched by them. At least **three dimensions** of pervasiveness have to be given attention therefore with regard to the permeation of new technologies:

Fig. 1:

Fig.1: Permeation of new technologies



Dimensions of pervasiveness of "new" technologies

-Horizontally: between sectors (high technology and traditional sectors)

-vertically: between firms of different size (large, medium, and small firms)

-spatially: between regions (highly developed core and structurally weak peripheral or old industrial areas).

The crucial question therefore is to which extent innovation can be made pervasive and benefit an entire socio-economic system. This depends to a great extent on the level at which innovative action is taken, on the target actors addressed (external or regional) and on the interaction (synergy) between different actors at local/regional levels.

5. Major patterns of "induced" and "spontaneous" technological innovation

Like growth in the earlier growth centre policies, technological innovation has recently also been induced mainly in spatially concentrated form. Some of these efforts have been

- externally implanted by either central government or by large multi-locational/-national firms, others have been
- locally/regionally initiated by local government and universities, or have been
- initiated by local academics and entrepreneurs.

Of the three regional high-technology approaches defined by Luger (1984) they respectively tend to emphasize recruiting high-technology plants located elsewhere, to technologically advance resident "old line" businesses, and to incubate home-grown high-tech companies. The permeating effects differ accordingly.

A) Central government/large firms(s) externally implanted regional innovation

Two outstanding cases will be dealt with here by way of example:

Tsukuba Science City established by the Japanese central government at a distance of about 100 km from downtown Tokyo to house the research departments/institutes of central government agencies as well as a university, the nucleus of which was also transferred from Tokyo.

Inspite of its relatively long period of existence of 15 years, Tsukuba has maintained an enclave-like character in many respects: geographically it remained rather isolated due to cumbersome access from Tokyo and other parts of the country; sectorially it has until recently not been able to attract major industrial or private R & D activities and only in the past 2-3 years progress has been made in this direction. The international technology exposition Tsukuba Expo in 1985 was to give further impetus oriented mainly towards attracting large company R & D activities.

Spin-off effects for small enterprises, consulting services, local risk-financing companies etc. have remained small so far.

Sophia-Antipolis in Southern France is a further outstanding example.

It emerged on the basis of a concentration of R & D activities of large corporations such as IBM, Texas Instruments, Societe Nationale Industrielle Aerospatiale, Thomson, in the 1960's which were attracted by environmental advantages of the Cote d' Azur area (natural and urban milieu, fiscal advantages of Monte-Carlo). In 1974 Sophia-Antipolis was then created as a "city of knowledge and wisdom" at the initiative of leading personalities from Paris (Ecole de Mines, various ministries), and additional headquarters of international firms were induced by DATAR to locate there (Perrin and Kritly, 1986, p.9), along with the location of laboratories and research centres of universities and the National Science Research Centre. Separate from it, an industrial park Valbonne was then created for production activities, and both these units in 1985 were integrated to a new organization "Valbonne Sophia Antipolis" by a contract between the central State and the Region. The objective of this new organization is to bring the area to "maturity" by strengthening its public research and teaching (including university) potential and the cross-fertilization between research-training-product development and the availability of technological councelling and financing for innovative new and existing enterprises . In recent years there have in fact emerged about a dozen small new enterprises "by incubation" from collaborators of large enterprises or from graduates of the Grandes Ecoles, in specialized services, R + D and qualified production in informatics, bio-engineering, etc. Although these spin-offs at present are estimated to represent only one fifth of the total production capacity of the area, its share is reported to have an increasing trend (Perrin and Kritly, 1986, p.15).

These two examples show that even with the dominance of central technological initiatives (external to the region), regional permeating effects may differ depending on the breadth of activities promoted (R&D and/or other services, ptoduction, internal vs. external target firms, etc.) and on the local organizational structures available or created.

B) Local government and local university initiated innovation

A well-known example is **North Carolina Research Triangle Park**, created in 1959 at the initiative of the State Governor and three neighbouring universities (Duke University, University of North Carolina and N.C. State University). The major breakthrough came with locating there major national research centers such as the National Environmental Research Center and the National Institute of Environmental Health Sciences in 1965/6. This was accompanied by the location of large corporate research facilities there, and of production facilities near the park of companies such as IBM and Borroughs Wellcome Company (Premus 1985).

Although R.T.P. was initiated regionally, it focussed primarily on the attraction of national public or large private company research facilities from the outside. There appears to have been little spin-off to other firms or other (traditional) sectors in the region however which predominantly still "use traditional technologies and low-skilled workers, most notably in the textiles, apparel and furniture industries, -..... (and which) -.. alone account for 50 percent of manufacturing jobs" (Luger 1984, p.284). This is attributed to the fact that North Carolina's high-tech development strategy was oriented mainly towards exogenous factors, i.e. the recruitment of outside firms and little on the modernization of existing local or the emergence of new firms (p.287).

The **Japanese Technopolis Policy** is another well-known example where local government, local university and (mainly local) enterprise interact closely. This local interaction and the complementary support given by central government has been analyzed by this author elsewhere (Stöhr 1986). Development in a number of these Technopolis sites started by attracting branch plants of external (international or Japanese) large high-tech firms, but in some of them such as Oita it appears to have meanwhile been possible to diversify the structure substantially by the creation of local service firms and by the promotion of small/medium indigenous high-tech firms. Exogenous factors thereby have increasingly been endogenized. Further analyses on these aspects are hoped to be available to this author soon.

Comparative analyses of university and local government-related science parks have been made for several countries (Krist 1984, Levitt 1985) but they hardly include factual data on the questions raised in this and the following sections of the present paper.

C) Local enterprise/community initiated "spontaneous" innovation

Such "spontaneous" local/regional enterprise initiated innovation complexes are likely to be much more numerous than those in the preceding catagories. They are however less systematically reported on. Historically, most technological development and regional technological innovation took place by "spontaneous" entrepreneurial initiative. Even in our present time however, there remain a great number of cases where regional technological innovation takes place "spontaneously" by the initiative of local entrepreneurs or local communities. Often this can be considered an endogenous survival strategy of locally rooted (frequently medium/small) entrepreneurs or social groups in disadvantaged areas where government policies are little effective. For these enterprises and regions it is an alternative to attempting to develop via the attraction of branch plants of external firms as under A) above.

Two relatively large-scale examples of such regional innovation complexes of medium/small scale enterprises in peripheral areas have been analysed by this author elsewhere, the experiences of the Mondragon Cooperative Federation and of so-called "Third Italy" (Stöhr 1985/b). There are certainly a great number more of such examples but they have never been systematically compiled and analyzed, although they would constitute learning experiences of great value particularly on how to create regional innovation with little central government or other external inputs.

D) Local academics and potential entrepreneur initiated "start-ups" and "incubators"

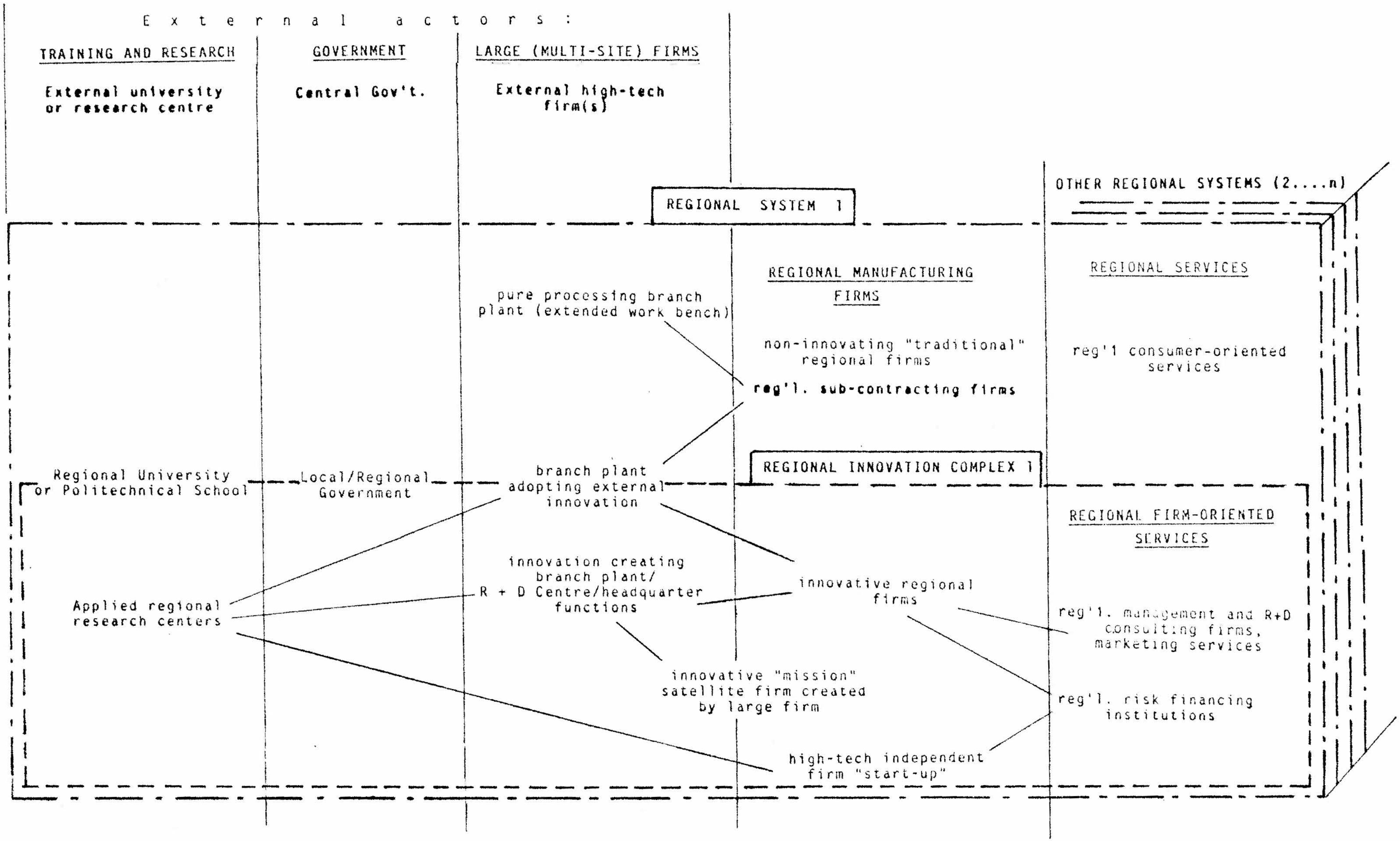
The non-institutionalized start-up of potential entrepreneurs of the initial Silicon Valley type, characterized by academic graduates becoming entrepreneurs, by high-tech sectors, small firms and fierce competition are widely considered a matter of the past in their pure form. Increasingly they seem to have become dominated by large companies farming out routine activities to low wage areas/countries and gaining monopoly control over new technology and markets (Dyckman 1985). In these cases a renewed externalization seems to have taken place. - In mixed form these small enterprise incubator functions are retained however in many of the German "Gründerzentren" (Krist 1984).

6. A framework for evaluating the permeating effects of innovation

Considering the potentially pervasive character of new technologies and the general objective that technological development should not aim only at restricted enclaves of an economy and society, it seems important to evaluate the degree to which different policies for technological development benefit broad strata of economy and society.

The main elements of such a framework are shown in Figure 2 which contains: innovation actors external to the region (top left: external training and research, central government, and multi-regional firms) as well as actors within the respective regional system (enclosed by interrupted lines in Fig.2). This regional system contains the potential actors of a "regional innovation complex" (lower part) and the usually not innovation inducing economic components such as regional traditional firms, consumer oriented services, purely processing branch plants and sub-contracting firms (upper part of "regional system"). - The actors of a potential "regional innovation complex" (Stöhr 1986/a) such as regional applied research centers, regional consulting and marketing firms, risk financing institutions, etc. are shown in the lower part of Fig. 2. Regional universities /politechnical schools and local /regional government can potentially play an innovative role which is not always fulfilled however. The importance of the synergetic interaction amongst them and with regional production units has been shown in Stöhr 1986/a.

Fig.2: Elements for evaluating the permeating effect of externally/regionally induced innovation



A) Externally induced regional innovation

In many cases innovation strategies are conceived externally (to the region) or by central agencies and rely mainly on the **recruitment of external high technology firms** (or branches thereof, see also 5/A and /B above). In figure 2 they would start at the top left. Important questions in these cases are:

> **If external firms** locate only **pure (routine) processing plants** ("extended work benches") in the area concerned without own R & D/management functions,
>
> **-do innovative effects emerge for regional sub-contracting firms ?**
>
> If external firms locate in the area **branch plants adapting external innovation** to specific products or specific regional conditions, to which extent
>
> - are they also **locating their own R & D functions** within the area ?
> - are they **using regional management and R & D consulting firms ?**
> - Are there **innovative effects** emerging **for regional subcontracting firms** or other innovative regional firms ?
> - **technical relations** emerging **with regional research or training institutions ?**
>
> **If external firms** locate an **innovation-creating plant with own R & D** or a **pure R & D center,** are there
>
> - **relations with regional research or training institutes** emerging ?
> - **relations with innovative regional firms** and/or with regional management/R & D **consulting firms** emerging ?

In some cases large firms create small **innovative "mission" satelites** in order to develop new products or test new processes; what are their effects in the above respects ?

A further question in all the above cases is to which extent innovative independent firms or branch plants within the region have **innovative effects also on the traditional non-innovative** sectors within the region.

B) Regionally induced innovation

In many cases however innovation is also locally/regionally induced, e.g. by local firms, local academics/universities and potential local entrepreneurs (see also 5/C and /D) above). In these cases relevant questions will be: to which extent

- do **local high-tech firms** also have an **innovative effect on other sectors** in the region ?
- have **relations** between regional firms and **regional research and training centers, regional management and R & D consulting firms, regional risk financing** institutions emerged and contributed to this innovation ?
- have **regional innovative firms** been able to **maintain their independence**? If they have become integrated (bought up etc.) by large external firms, to which extent have they retained **innovative effects on the region ?**

A further question relevant to all the above types of innovation would be whether the technological upgrading has been restricted to the locality of, e.g. a the science park, or whether it has also had a **positive impact on other, particularly neighbouring areas and regions.**

In summary, important **criteria for success of technological innovation** would be that

broad technological upgrading takes place including

- both high-tech and traditional sectors,
- different sizes of firms such as large, medium and small ones,
- not only the respective science park area but also neighbouring localities and regions.

a broad upgrading of job qualifications, including not only highly skilled but also medium and lower qualification strata of male as well as female jobs, avoiding the frequently encountered "bifurcation" of labour markets in high-tech regions,

a broad increase in activities which serve as a **basis for self-sustaining technological upgrading,** particularly private and public R & D activities, training, consulting, financing and organisational services able to sustain technological and organisational change in an interactive way,

retention/increase in **competitiveness** of externally oriented economic activities,

retention/increase in **number of available jobs,**

retention/increase in **existing wage levels,**

retention/increase in **levels of environmental quality,** including natural and built-up environment, traffic conditions, air and water conditions, etc.

Further important criteria for sustained success of these innovation processes are the **establishment/improvement of organisational structures for**

the solution of potential social conflict at plant, regional or other levels especially regarding

-the **organisation of work** in connection with technological innovation,

-the **creation of new jobs** or other activities if technological change reduces the number of jobs available,

-the **distribution of income** deriving from technological innovation,

the **identification of potential new markets, new products, and new technologies** available and useful for firms and activities in the region,

the constructive and mutually stimulating **interaction between key organisations/actors for innovation within the region,** particularly local/regional government, regional training and research functions, regional R & D and managerial consulting services, financing institutions, manufacturing firms and labor organisations (see also Stöhr 1986/a).

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